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# Ignition Patterns & Prescribed Fire Behavior in Southern Pine Stands

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*ABSTRACT:* As an aid to forest managers who use or contemplate using aerial ignition techniques in their prescribed burning programs, a study was designed to evaluate the magnitude of the differences that could occur depending on whether lines of fire were used (ignited by a helitorch) or a spot-fire technique was used (ignited by aerial ignition devices). Six experimental fires of a simultaneously ignited backfire, flank fires, and headfires of line origin and spot origin were observed, and flame spread distances were recorded at 1-minute intervals to time of burnout. Of special note were the differences in rate of spread of headfires from line and spot origin during early development. Headfires of line origin traveled at rates that varied from 1.5 to 5.9 times faster than those of spot origin. Line fires would, therefore, develop higher fire intensities than spot fires.

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## INTRODUCTION

Aerial ignition continues to be looked upon with favor in the South as a means of prescribed burning the understories of pine stands. An advantageous aspect of the technique is the speed with which areas can be ignited and burned out, which thus allows for better utilization of favorable burning weather (Johansen 1984a). The rapid burnout may also prove to be the technique's undoing if unwanted fire intensities develop too often and cause excessive damage to the overstory crop trees (Johansen 1984b).

Only two basic types of ignition from aircraft are currently being used: lines of fire by means of a flying drip torch or helitorch (Muraro 1976, Lowman 1982), and spot fires (or point source) by means of an aerial ignition device (A.I.D.). For fuel, the helitorch uses regular gas mixed with Alumagel, a dry metallic stearate available from WITO Chemical Corp., Houston, Texas (Stevens 1985). The A.I.D. system has a dispenser that injects ethylene glycol into plastic spheres (similar to ping-pong balls) containing potassium permanganate, which are than released (Lait and Muraro 1979). The originating fire behavior that stems from these two types of ignition can be quite different (Rothermel 1984).

A field study was designed to measure the extent of the differences that would occur when line-fire and spot-fire ignitions were made in palmetto-gallberry type fuels under 18- to 25-year-old plantations of slash pine (*Pinus elliottii* Engelm. var *elliottii*) under differing weather and fuel conditions. All burning took place on the Dixon Memorial State Forest in Ware County, Georgia.

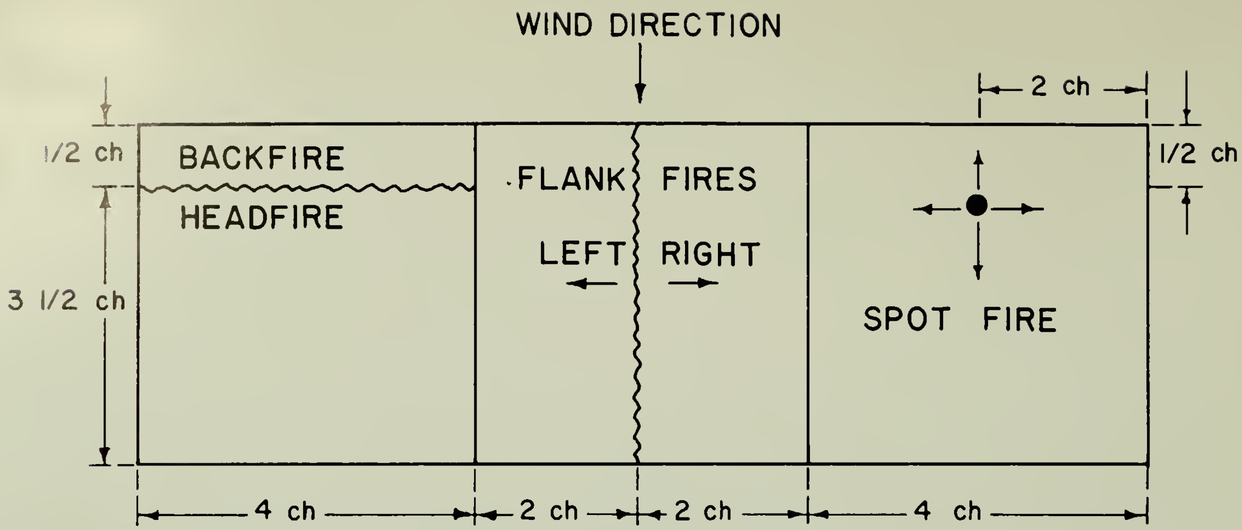


*Figure 1.--Layout of single experimental burn for simultaneous ignition and burning of a headfire, backfire, flank fires, and spot fire.*

## PROCEDURES

Six experimental fires involved simultaneous ignitions in each of three 4- X 4-chain (1.6 acre) blocks (Figure 1). One block contained a headfire and backfire ignited from a single drip torch. The second block had two directional flank fires ignited by a single drip torch line from downwind to upwind. The third block had a single spot fire ignited with matches when the other two lines were initiated, which allowed flames to develop downwind, upwind, and crosswind. The two 4-chain drip-torch lines of fire were completely ignited within 45 seconds (fast walk).

The experimental fires were completed in a 2-year period under varying environmental conditions. For each set of the three-block fires, six people were used to observe the following fire movements: line head, line back, right flank, left flank, spot head, and spot back. Each person marked the fire's progress at 1-minute intervals in the center region of the burn. Lids from 1-gallon paint cans were used to mark the interval location of fire advance. Following burnout, the distance of each lid from fire origin was measured with a tape and recorded according to time elapsed since ignition. Linear rate of fire spread was then calculated from these data.

Several 1/4-milacre litter-vegetation samples were collected from the first four sets of burning plots before ignition to estimate available fuel consumed during the fires. Fuel amounts, based on duration of accumulation or "age of rough," were estimated on the last two plot sets. Only areas with litter roughs between 1 and 3 years of age were chosen

Table 1.Environmental conditions associations with ignition patterns of six experimental fires.

| Exp. burn (No.) | Burn date | Ignition time | Fire weather observations: Ambient temp. | Relative humidity | Wind-speed[a] | Mean available fine fuel | Mean Surface litter moisture content[b] |
|---|---|---|---|---|---|---|---|
| | | Hours | °F | Percent | mph | Tons/Acre | Percent |
| 1 | 1/30/84 | 1545 | 66 | 53 | 2.8 | 3.3 | 32 |
| 2 | 1/31/84 | 1130 | 47 | 46 | 2.0 | 3.7 | 34 |
| 3 | 1/31/84 | 1450 | 55 | 43 | 2.3 | 4.3 | 30 |
| 4 | 1/22/85 | 1300 | 43 | 34 | 2.0 | 3.0 | 24 |
| 5 | 1/22/85 | 1530 | 46 | 32 | 2.5 | 4.5[c] | 23 |
| 6 | 1/29/86 | 1145 | 60 | 63 | 3.0 | 4.0[c] | 29 |

[a]Measured at a 5.0-foot height in the stand.

[b]Each value based on nine samples.

[c]Estimate based on stand density and age of rough.

for the study so that all understory fuel accumulations were relatively light. Three upper-surface litter samples were collected from each plot immediately before ignition to determine moisture content. Temperature, relative humidity, windspeed at the 5-foot level in the stand, and prevailing wind direction were also measured. A recording anemometer was set up ½ chain upwind of the center plot and run during the course of the burns conducted in 1984 to measure windspeed and wind direction; only a hand-held Dwyer anemometer was used immediately before ignition to measure windspeed for the last three burns. Table 1 gives a summary of fire weather elements and fuel characteristics for each set of fires.

## RESULTS

Of the measured differences in fire behavior (Table 2), some were predictable--such as the lowest rates of spread occurring with backfires. The flank fires were difficult to keep maintained as such. If the line of fire from which the flanks developed was not set perfectly into the wind, one flank would be moving as a headfire most of the time while the other would move primarily as a backfire. Minor wind shifts would cause the same problem. Under high fuel moisture conditions the flank that was backing would frequently go out. The differences in fire behavior exhibited between headfires of line origin and those of spot origin were of special interest. To give some perspective on the disparities between them, two figures depict the forward spread distance plotted over elapsed time: The headfire of spot origin with the greatest spread rate is compared with the associated line headfire (Figure 2), and the headfire of line origin that had the greatest rate of spread is compared with the spot fire burning at the same time (Figure 3). In a run of approximately 250 feet for all six sets of fires, the headfires of line origin traveled at rates that varied from 1.5 to 5.9 times faster than those originating from spots (Table 2). The exception, 31 times faster, was a special case. In no instance did a spot fire advance faster than a line fire.

## CONCLUSIONS

Results from this study indicate that under any weather conditions where fire spread can be sustained, a headfire of line origin will always advance in its early stages at a rate considerably faster than would be the case had the fire been of spot origin. This means that in the early stages of fire development, the fireline intensity (Byram 1959) at the head of each of a group of multiple spot fires along a given length of line will be considerably less than anywhere along a line headfire of the same line length under the same conditions of fuel and weather. Therefore, the rate of heat output per unit of time for a given area will be greatly reduced by spot-fire use; this, in turn, will considerably reduce the height level at which needles would be scorched in a stand (Van Wagner 1973). This does not preclude the use of line fire (by means of a helitorch) to underburn a stand of pine to reduce fuel buildup. However, it does suggest that more care must be exercised in prescribing fuel and weather conditions to prevent excessive heat buildup that could unduly damage a forest stand.

This information can be extrapolated to a comparison of the helitorch with Alumagel and the A.I.D. system. The current technique is to pump Alumagel from the torch in a thin stream that breaks up into individual "globs" of burning gel as it falls to the ground. The rate of breakup and size of globs is dependent on pumping rate, aircraft speed, drop height, and gel viscosity. To date, it is impossible to regulate the spacing between globs due to the difficulty of regulating gel viscosity. Viscosity is strongly affected by age of the Alumagel powder, how the powder is stored, additives in the gasoline used, temperature of gasoline when mixed, mixing procedure, and the time allowed for gelling to take place. Because of all these uncertainties, Alumagel is usually dispensed in a steady stream with ignited globs falling to the forest floor at spacings from 5 to 30 feet apart. Technically speaking, this could be called spot firing; but it is actually line firing because these closely spaced spots quickly merge to form a line of fire.

Use of the A.I.D system will permit the forest manager to continue underburning pine stands after the helitorch user should stop. In all cases, however, the key to the successful use of any aerial ignition techniques is to know when to halt operations. Constant vigilance of the usually increasing fire intensity development as surface fuel moisture decreases from morning to mid-afternoon will allow the burn manager to stop stringing fire when heat begins to reach critical levels in the tree crowns. Burning under stands that are 30 feet tall will require earlier shutdown than burning under 80-foot stands.

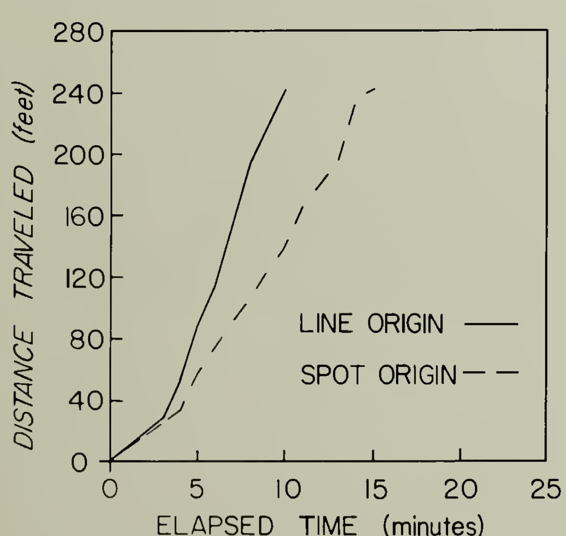


*Figure 2.--Spread rate of headfires of spot origin and line origin for experimental burn No. 1, 1/30/84 at 1545 hours.*

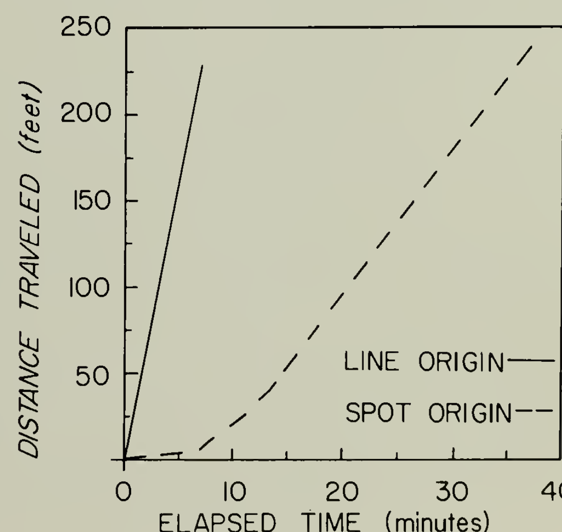


*Figure 3.--Spread rate of headfires of spot origin and line origin for experimental burn No. 5, 1/22/85 at 1530 hours.*

Table 2. Fire spread characteristics associated with ignition patterns of six experimental fires.

| Exp. burn (No.) | Elapsed time to burnout: Line fire | | Spot fire | | Flank fire | | Linear spread distance: Line fire | | Spot fire | | Flank fire | | Mean rate of advance: Line fire | | Spot fire | | Flank fire | | Spread rate ratio of line head: spot head |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Head | Back | Head | Back | Left | Right | Head | Back | Head | Back | Left | Right | Head | Back | Head | Back | Left | Right | |
| | Minutes | | | | | | Feet | | | | | | Feet/Minute | | | | | | |
| 1 | 10 | 13 | 15 | 0[a] | 13 | 12 | 242 | 6 | 241 | 0 | 86 | 25 | 24.2 | 0.5 | 16.4 | –– | 6.6 | 2.1 | 1.5 |
| 2 | 21 | 21 | 26 | 22 | 0[a] | 15 | 204 | 12 | 61 | 7 | 0 | 81 | 9.7 | 0.6 | 2.3 | 0.3 | –– | 5.4 | 4.2 |
| 3 | 18 | 23 | 31 | 25 | 0[a] | 30 | 266 | 7 | 76 | 14 | 0 | 95 | 14.8 | 0.3 | 2.5 | 0.6 | –– | 3.2 | 5.9 |
| 4 | 11 | 0[a] | 14 | 24 | 0[a] | 25 | 239 | 0 | 10 | 14 | 0 | 42 | 21.7 | –– | 0.7[b] | 0.6 | –– | 1.7 | 31.0 |
| 5 | 7 | 29 | 37 | 24 | 28 | 23 | 230 | 14 | 243 | 13 | 59 | 39 | 32.9 | 0.5 | 6.6 | 0.5 | 2.1 | 1.7 | 5.0 |
| 6 | 11.5 | 36 | 36 | ––[c] | 45 | 25 | 230 | 45 | 244 | –– | 148 | 139 | 20.0 | 1.2 | 6.8 | –– | 3.3 | 5.6 | 2.9 |

[a] Ignition failed to spread.
[b] Ignition failed to sustain itself after advancing only 10 feet.
[c] This fire was not manned.

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